BUILDING A MATHEMATICAL MODEL RELATED TO ELECTRICITY CONSUMPTION IN SAILBOATS

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ABSTRACT

This article reports on the implementation of a mathematical modeling activity about renewable energy. The activity was first implemented with twenty-four 10th grade students in a state high school in Turkey and lasted 2 lesson hours. Then, the revised version of the activity was implemented with four 10th grade students. Students built a mathematical model of the electricity consumption on a sailboat, and then decided which renewable energy source could be used on the boat using their models. The students experienced all stages of mathematical modeling: real life problem, mathematical problem, mathematical solution, and interpreting the solution. The students found a solution to the modeling problem by creating and interpreting tables, graphs, and functions, and by comparing the different graphs resulting from real life situations. Additionally, they increased awareness about renewable energy sources. The activity might provide an example application of mathematical modeling for mathematics educators.

Keywords: mathematical modeling, renewable energy, linear functions, mathematics education.

YELKENLİ TEKNEDE ELEKTRİK TÜKETİMİYLE İLGİLİ BİR MATEMATİKSEL MODEL OLUŞTURMA ETKİNLİĞİ

ÖZ

Bu makalede, yenilenebilir enerji konusu üzerine tasarlanan bir matematiksel modelleme etkinliği paylaşılmıştır. Etkinlik, ilk olarak Ege bölgesinde orta ölçekli bir ilin bir devlet lisesinde 24 tane 10. sınıf öğrencisiyle 2 ders saati süresinde uygulanmıştır. Yapılan bazı değişikliklerden sonra etkinlik 4 tane 10. sınıf öğrencisiyle tekrar uygulanmıştır. Öğrenciler, yelkenli bir teknede tüketilebilecek elektriği gösteren bir matematiksel model geliştirmişler, daha sonra bu modellerini kullanarak teknede hangi yenilenebilir enerji kaynağının kullanılabileceği konusunda karar vermişlerdir. Matematiksel modellemenin; gerçek yaşam problemi, matematiksel problem, matematiksel çözüm ve çözümü gerçek yaşama uyarlama basamakları öğrenciler tarafından deneyimlenmiştir. Matematiksel açıdan, öğrenciler, tablo, grafik ve fonksiyon oluşturmuşlar, bu gösterimlerde temsil edilen verileri yorumlamışlar ve gerçek yaşam durumundan kaynaklanan farklı grafikleri karşılaştırarak modelleme problemine çözüm bulmuşlardır. Ek olarak, öğrencilerin yenilenebilir enerji kaynakları hakkında bilgileri ve enerji kullanımında tasarruf etmekle ilgili farkındalıkları artmıştır. Makalede paylaşılan etkinliğin, matematik eğitimcilerine matematiksel modelleme alanında örnek bir uygulama sunacağı düşünülmektedir.

Anahtar kelimeler: matematiksel modelleme, yenilenebilir enerji, doğrusal fonksiyon, matematik eğitimi.

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INTRODUCTION

Lofgren, Collins, Smith, and Cartwright (2016) taught mathematical modeling to public health professionals by using the zombie context. In the workshop, by considering the epidemic diseases of zombies, how to utilize mathematical modeling in order to make sense of the epidemic diseases in biology and epidemiology was discussed. In the field of criminology, Canter, Coffey, Huntley, and Missen (2000) investigated how to estimate the locations of serial killers by using mathematical modeling. Orlob (1983) examined the quality of water in rivers, lakes, and water reservoirs drawing on mathematical modeling. These examples illustrate that mathematical modeling is used in many areas such as biology, engineering, economics, and computer science. What is mathematical modeling? Why is it important? What is its role in the education system? In this article, firstly mathematical modeling is defined, its importance is explained, and then an activity which uses mathematical modeling and its implementation process are described.

Bliss, Fowler, and Galluzo (2014) defined the *mathematical model* as a representation created for quantitative or qualitative understanding of a real life situation. The model is also used for making future predictions about the situation. *Mathematical modeling* can be defined as analyzing a real life situation using mathematics and the process of building a mathematical model (Erbaş et al., 2014). Cirillo, Pelesko, Felton-Koestler, and Rubel (2016) highlighted some common features of mathematical modeling definitions made by different researchers. The first is that mathematical modeling is authentically related to everyday life. These problems arise from daily life situations. Unlike the well-defined, often precise and single-answer problems in textbooks, modeling problems often involve uncertainties and are complex. The person who solves the problem should determine the limitations of the problem, and define the variables. The second common point in the modeling definitions is that the mathematical modeling problems are solved to understand a real life situation, to develop explanations about the situation, and to predict the future of the situation. The third common point is that the mathematical modeling process engages

the problem solvers in creative thinking, and they use the intellectual processes such as making decisions and making selections. The fourth common point is that mathematical modeling is a repetitive process. If the developed model fails to explain a real life phenomenon, the model should be revised and tested again with the real life situation. The last common point identified is that in the modeling process, the solution is usually not unique and precise. Different solutions can be reached when the problem is restricted by different limitations and variables.

At first glance, mathematical modeling can be confused with the word problems found in the textbooks. Bliss et al. (2014) used two examples of recycling to compare mathematical modeling problems with word problems. In the question presented as a word problem, the population of a city and the ratio of the people who recycle plastic bottles were given, and the amount of bottles recycled in the city was asked. In this question, everything that is necessary to solve the problem is presented in the question, and the question has only one correct answer. In the other question, "How much plastic is recycled in Yourtown" (p. 6) was asked. In this second question, the person solving the problem needs to do some research and limit the question by deciding which variables will be used (for example, which plastics are taken into account, the number of people who recycle). The solution will change depending on the limitations and assumptions made. Another point is that in modeling problems, a model for a real life situation is explicitly asked in the question or the question can only be solved by creating a model.

In the related literature, mathematical modeling is often represented as a cyclical process by researchers (Cirillo et al., 2016; Erbaş et al., 2014). In this study, the mathematical modeling process, which is given in Figure 1 and was defined in the mathematics curriculum of Turkey in 2013, was used as the modeling framework (Ministry of National Education [MoNE], 2013). This mathematical modeling process begins with a problem related to real life. In the first step, real life problem, students should first make sense of the problem situation.
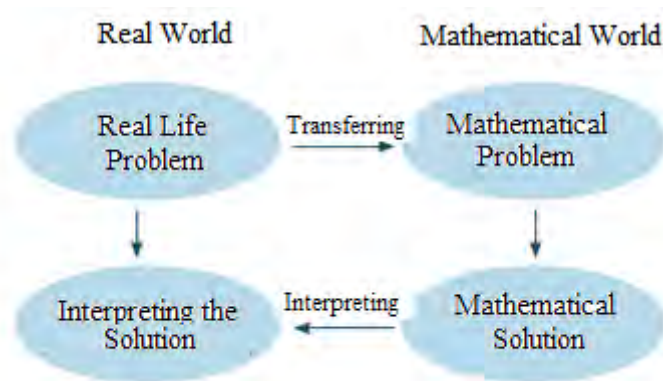
Figure 1. Mathematical Modeling Process (Translated from MoNE, 2013, p. V)

Making sense of the problem involves processes such as expressing the problem in different ways, creating sub-problems, making assumptions, and defining the variables related to the problem. Understanding the problem naturally results in the creation of a mathematical model (Bliss et al., 2014). In other words, the mathematical problem phase includes the expression of the real life situation with the mathematical language. The mathematical model can be a function, a graph, or a table (Erbaş et al., 2014). In the mathematical solution step, the problem is solved using the model. Interpreting the solution step involves checking whether the solution found is meaningful in the context of the problem and testing whether the model works well. If the model needs to be revised, the process is repeated and a new solution is sought.

In this section, the differences between mathematical modeling and modeling mathematics will also be discussed, since they can be confused with each other (Cirillo et al., 2016). The representation of mathematical concepts with different representations such as drawings, tables, symbols is modeling of mathematics. For example, doing the addition 8 + 7 with base 10 blocks is modeling the addition operation using concrete materials. Similarly, in the case of cracking two out of 10 eggs and calculating how many eggs are left, the subtraction process is modeled by a real life situation (Lesh, Post, & Behr, 1987). The starting point for modeling mathematics is mathematics' own world and the aim is to study a mathematical concept or procedure. On the other hand, the starting point in mathematical modeling is real life, and the aim

is to examine, analyze, and evaluate a real life situation using mathematics.

Mathematical models make it easier for scientists to analyze the problems and find solutions by transferring the situations to abstract representations (Bliss et al., 2014). Therefore, it is frequently used in many disciplines as mentioned at the beginning of the article. The importance of mathematical modeling could also be seen in recently developed mathematics programs (MoNE, 2013; National Governors Association Center for Best Practices, 2010). There has been particular importance given to modeling in the programs. For instance, the Next Generation Science Standards (NGSS) document, which defined science standards and was published in the United States, included mathematical modeling as a science and engineering skill, and its role in connecting mathematics and science was emphasized (NGSS Lead States, 2013). The reasons why mathematical modeling has been included in the curricula involves factors such as the process of mathematical modeling contributes to the development of higher level thinking and problem-solving skills of students and help them value mathematics by experiencing how mathematics is used in real life (Doruk & Umay, 2011; MoNE, 2013) . An activity that was developed and implemented in order to contribute to the more widespread application of mathematical modeling in schools is described in the following sections of this article. This study might contribute to the literature in this field since in the activity all steps of the modeling process are experienced by the students and the students' participation processes are examined.

ACTIVITY IMPLEMENTATION

Contextual Background

Since the province where the activity was implemented was a seaside settlement, the researcher (author) aimed to create a modeling problem related to boats. In order to raise awareness on renewable energy sources, research was carried out on solar panels and wind turbines. Modeling problems originate from authentic real-life situations. The author spoke with sailors, researched the internet on this subject, and wrote a modeling problem that could indeed arise in maritime life to provide energy using renewable energy sources. The data used when designing the activity worksheet is close to the actual values. After the necessary permits were obtained from the Directorate of National Education, the activity was implemented in a Social Sciences High School located in a medium-sized province in the Aegean Region in Turkey.

The activity is aligned with the following standards of the high school mathematics program of MoNE (2018): 10.2.1.2. Plots graphs of functions. 10.2.1.3. Interprets graphs of functions. 10.2.1.4. Represents the appropriate real life situations using linear functions. One of the goals of the activity is to help students to experience all the steps of mathematical modeling while solving a real life problem about renewable energy sources. Other goals of the activity involved helping students to realize that some situations encountered in daily life can be represented by functions and engaging them in drawing and interpreting the graphs of these situations.

In the second term of the 2017-2018 academic year, the activity was implemented in a 10th grade class and lasted 2 lesson hours (80 minutes). There were 24 students in the class. The students participated in the activity by forming pairs with the students sitting next to them. Based on the observations made in this first implementation, the activity was slightly revised and the revised activity was taught to four students who recently graduated from the 10th grade. These four students, who were attending different schools (Anatolian High School, Science High School, and Private High School), defined their mathematics achievement level as medium. The next section

of the paper, the implementation section, was written mostly based on the whole class teaching. However, from time to time, findings from the small group teaching were also reported. The materials used in the activity are the worksheet given in Appendix 1 and the graph paper given in Appendix 2.

Implementation

In the motivation phase of the lesson, the students were asked what renewable energy meant. The class discussed about the differences between fossil fuels and renewable energy sources. It was discussed that fossil fuels have a limited life span and are harmful for the environment whereas the renewable energy sources are natural resources such as solar, wind, and water and these sources are not harmful to nature. It was emphasized that the use of renewable energy sources should be encouraged.

After this discussion, the worksheets were distributed and the students were asked to read the problem first. Then the students explained what they understood about the problem. The problem on the worksheet is as follows.

> *Suppose that you bought a new sailboat. You aim to use renewable energy sources in your boat. Your financial situation is only enough to buy a solar panel or a wind turbine generating an average of 2100 watts of electricity per day. Which energy source would you prefer? Explain the rationale of your choice by creating a mathematical model.*

One of the students summarized the problem by saying "If we had a boat, we are asked to decide which energy source, wind or solar, we would use to generate energy on this boat."

After discussing the problem situation, the students were asked to work together with their partners to determine the amount of electricity that they could consume within one day in the boat. For this purpose, the students read the first question on the worksheet and completed the table in this question. In this question, there were some students asking the meaning of some terms in the table. The teacher explained the meanings of unknown terms to the class. For example, the *electric winch* is a tool for wrapping the ropes with little force. It is used to wrap the ropes of sails. The *electric*

windlass is used to wind or to release the chain during anchoring. One of the objectives of the first question is to increase the knowledge of the students about boat culture, electricity consumption, electrical appliances, and to raise awareness on the economic use of electricity in boats. Another goal is to help students transform the real life problem into a mathematics problem. Upon completion of this question, the basic data source of the mathematical model to be created is obtained.

Students were frequently reminded that the maximum amount of electricity they could use was 2100 watts when filling the table in the first question. In the beginning, some students thought that they could use all the electrical devices in the table, and when they saw the maximum amount of electricity, they revised their tables and gave up using some devices. For example, a student commented: "I think we can wash the dishes and we don't use the dishwasher." During this part of the lesson, the teacher observed that the students had conversations about how much electricity some electrical tools consumed. A table completed by a group is given in Figure 2. This group assumes, for example, that there will be 3 hours per day for the refrigerator and 2 hours for the music set, but the oven will never be used. The estimated total daily electricity consumption is 2070 watts.

Elektrikli Alet	Saatte Tüketilen Elektrik (watt)	Kullanım Süresi (saat)	Günlük Elektrik Tüketimi
Buzdolabı	60	3	180
Buzluk	70	2	140
Aydınlatma	120	1	120
Televizyon	75	0	0
Müzik Seti	50	2	100
Laptop	50	0	0
Fırın	1800	0	0
Bulaşık makinesi	1800	0	0
Çamaşır Makinası	800	1	800
Ütü	2700	0	0
Kahve Makinası	900	0	0
Eletrikli vinç	1000	0,25	260
Eletrikli Irgat	1000	0,25	250
Navigasyon Cihazı	50	1	50
Otopilot	60	2	120
Hidrofor	120	0,5 saat	60
Toplam		13,5	2 070

Figure 2. Electricity Consumption of a Group

After filling the electricity consumption table in the first question, the students were informed about the distribution of electricity consumption table in the second question. With their partners, the students planned the distribution of electricity consumption by time and wrote how this consumption was distributed within a day. In this question, some groups could not comprehend how to complete the table at the beginning. However, the teacher told them that they would not use an electrical appliance all day and asked the students to indicate which of the appliances in the previous table they could use at which time of the day. Figure 3 shows the table created by the group whose table for the first question was given in Figure 2. The numbers in the last row of the table given in Figure 3 add up to 2070 watts, and it is compatible with the first table in Figure 2. With the completion of the table in the second question, students built their electricity consumption models in table form. In this question, the student groups talked to each other about the models they created. For example, a student said "we only used the coffee machine for 5 minutes." These kinds of communications showed that the model of each group could be different based on the group's choices.

Saat	7:00-9:00	9:00-11:00	11:00-13:00	13:00-15:00	15:00-17:00	17:00-19:00	19:00-21:00	21:00-23:00	23:00-01:00	01:00-03:00	03:00-05:00	05:00-07:00
Tüketilen Elektrik Miktarı (watt)		140	250 250 50	100	60 90	120	120	800	90			
Toplam:		140	550	100	150	120	120	800	90			

Figure 3. Distribution of Electricity Consumption of a Group

Students were then given graph papers (Appendix 2). Each student in each group received a separate graph paper. Each student was asked to draw a graph of the total consumption of electricity versus time. In this part of the lesson, the students represented their mathematical models in graphical form. Before students started to plot their graphs, the teacher started a discussion about which variable to use on which axis. The teacher asked the class "This will be a graph of the total electricity consumption versus time. Which variables should the x and y axes include and why?" The students easily reached the distinction of dependent and independent variables and stated that the time variable was independent and therefore the x axis should show time. Similarly, they decided that total energy consumed changes according to time and therefore should be the title given to y axis.

Students, using the table created in the second question, plotted the graph of total electricity consumption versus time. In this process, some

students had difficulty in plotting their graphs because they did not consider the warning on the worksheet (Take 7:00 am in the morning as zero when creating the time axis). Some groups found it difficult to decide which points should be included in the graph. Some groups started to plot their graphs using the values for the electricity consumed at the time intervals instead of using the total consumed electricity (cumulative total). The teacher warned the class to accept 7:00 am in the morning as zero and to determine the total amount of electricity consumed during the day while determining the points to be plotted. With the experience gained from the first implementation of the activity, a third row with the title "Cumulative total" has been added to the table in the second question of the worksheet. Also, an explanation has been added to the third question to ask students to use this row for plotting their graphs. In the second implementation with four students, there was no need to make an additional explanation for drawing the graph and the students successfully created their graphs. There was one student who did not pay attention to the proportion in the numbering of the axes, and the teacher reminded that equal values should be assigned to equal intervals. The graph of the table given in Figure 3 is presented in Figure 4.
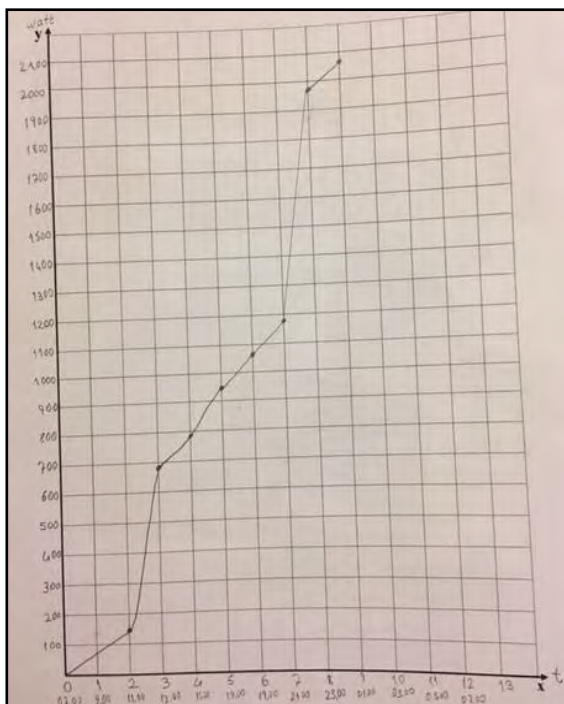

Figure 4. The Graph of Total Electricity Consumption Versus Time

In the next part of the lesson, the students were asked to review the table in the fourth question on the worksheet. By looking at this table, they were asked to predict which option they would choose and write the reason for their choice. The teacher hung a paper on the wall containing the advantages and disadvantages of the solar panel and the wind turbine and told the groups that they could come and read this information. The advantages of solar panel included:

- Solar panel only has installation costs.
- It is resistant to sea water and different weather conditions.
- You can walk on it.
- It does not make noise.
- It does not have any moving parts.
- Cleaning up once in a while is enough.

Disadvantages of solar panel:
- Solar panels occupy a lot of space.
- Suitable temperature and solar radiation are needed to generate energy.

Advantages of wind turbine:
- Wind turbine only has installation costs.
- It takes up less space and is installed on a mast.
- It can produce electricity 24 hours if there are favorable conditions.
- It is sufficient to lubricate once in a while. No special cleaning required.
- Wind turbine repairs are usually cheaper than solar panels.

Disadvantages of wind turbine:
- Wind turbine has moving parts.
- It is important to have proper wind for electricity generation.

The students were asked about their initial predictions of which energy source they would choose: solar panel or wind turbine. Some groups chose the wind turbine while others chose the solar panel. At this stage, students' preferences were mostly based on the advantages and disadvantages of both renewable energy sources. For example, a group's reason for choosing a wind turbine was that it is cheaper to repair a wind turbine as shown in Figure 5.

Figure 5. A Group's Initial Choice of an Energy Source

Another group indicated that they would choose solar panel because the solar panel was safer as seen in their explanations given in Figure 6. The moving parts of the wind turbine could pose a danger.

Figure 6. Another Group's Initial Choice of an Energy Source

The students plotted electricity generation graphs as part of the fifth question that was asked to guide the students to select an energy source based on their electricity consumption models. The aim of the sixth problem in which these graphs were interpreted in the context of the problem is to cover the "mathematical solution" and "interpreting the solution" steps of the mathematical modeling process. Using these graphs, the students are able to determine which energy source is compatible with the mathematical model they built, in other words, find a solution to the problem asked at the beginning of the lesson. Moreover, the meaning of this solution can be discussed and the meaning of the solution in the real life situation can be explained. If necessary, the mathematical model can be revised.

During the lesson, the group members had previously drawn electricity consumption graphs. In the fifth question, one of the group members was asked to select the wind turbine and the other member was asked to select the solar panel. Each student plotted the electricity production graph of his/her choice of the energy source on the same coordinate axis that they had drawn their electricity consumption graph. Figure 7 and Figure 8 shows the electricity generation graphs of the group whose total electricity consumption graph was given in Figure 4.

When the students plotted their graphs of electricity generation, they were asked about what renewable energy source they preferred by examining their graphs (the sixth question). Each group interpreted their own graph and

identified the energy source that was compatible with their model. At this stage, a class discussion started and the students were asked to share their solutions with their classmates. They explained the reason for their choice of renewable energy source.
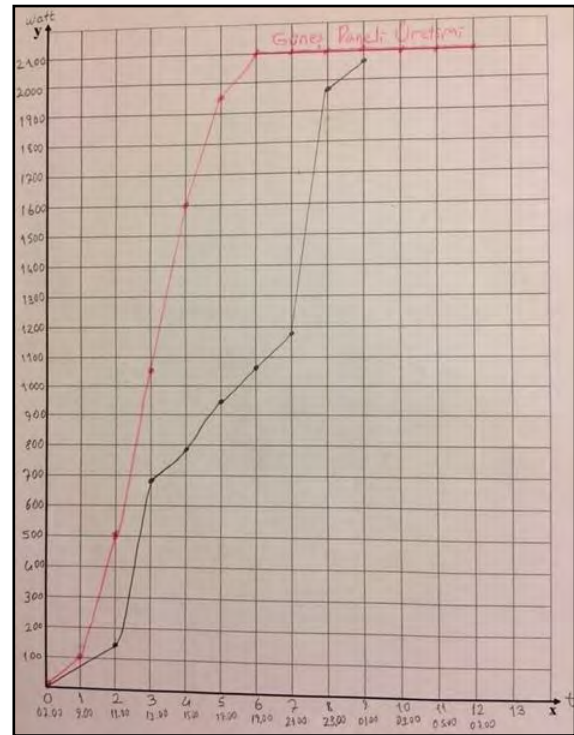

Figure 7. Solar Panel Electricity Generation Graph of a Group
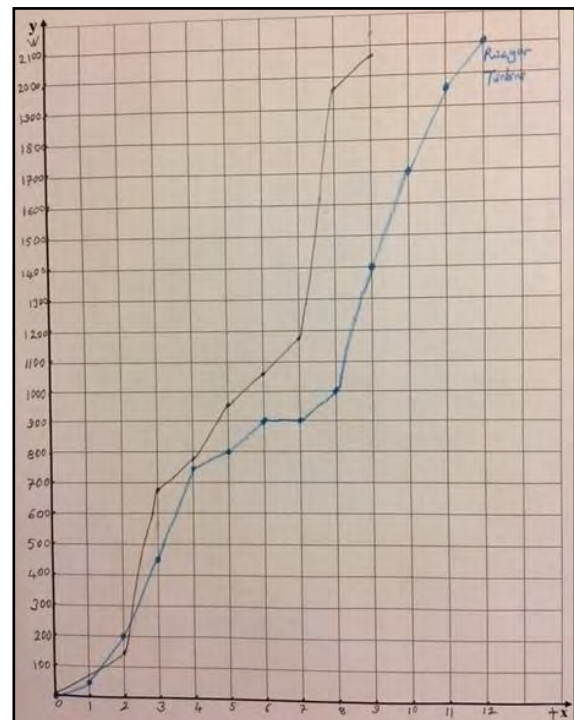

Figure 8. Wind Turbine Electricity Generation Graph of a Group

The electricity consumption model of the group whose graphs are presented in Figures 7 and 8 is not compatible with the wind turbine because the energy consumed is often more than the energy generated. In the solar panel, the energy generated meets the energy consumed. The group explained this in their response to the sixth question, their answer is shown in Figure 9.

Figure 9. Renewable Energy Source Choice of a Group

In this part of the lesson, the students were reminded that they could make changes in their models if necessary. There was not a group that changed the model except for one group. An explanation of the change made by this group is presented in Figure 10. This group reduced the 210 watts of energy they planned to use in the morning hours to 100 watts and made the model useful.

Figure 10. A Group's Explanation about Their Revised Model

The class discussion revealed that the models of the groups and their solutions differed. It was emphasized that mathematical situations encountered in daily life may have more than one correct answer. It was also discussed that mathematics could help people in decision making.

After the activity was taught to whole class, the author reflected on the lesson and thought that the mathematical dimension of the activity could be enriched. The seventh question was added to the worksheet to write the function representing the electricity generation of the solar panel. In the second implementation with four students, the students were asked about the general formula of the linear functions and the meaning of the parameters in the formula. The students said that the general formula of linear function was f(x) = ax + b, but they did not remember the meaning of a and b. About 4 months passed since they had learned the

subject. Therefore, the teacher reminded that "a" is equal to the slope of the line and "b" is the number at which the line intersects the y-axis. Students expressed that after 12 hours, electricity generation could be represented by the function f(x) = 2100. For the previous hours, they said that they could write a separate function for each line in the graph, but it would be very difficult and time-consuming. Then, they were asked to connect the first value of the graph (0,0) with the point at the 12th hour (12,2100), and write a function that represents the general tendency of the electricity generation using this line. The group discussed that this new line visually represents the electricity generation between 0-12 hours since it passes through the other points.

After the functions were determined, the group discussed about the meaning of the parameters. A part of this discussion is given below. The teacher is represented by the letter T, and the students are denoted by S1, S2, S3, and S4.

T: What is the meaning of the parameters in the function f(x)=175x?
(No response.)
T: How did you calculate 175?
S4: [Showing the triangle drawing] We divided the height by width.
T: What does this mean in terms of electricity generation?
S3: It produces 175 watts per hour on average.
T: The average amount of electricity generated per hour. Well this is for the parameter a. What is the value of the other parameter?
S2: Zero.
T: What does it mean?
S1: In the beginning there was no electricity.

Similarly, the parameters of f(x)=2100 are discussed. The slope of the line is zero meaning that there was no electricity production at night. The response to the seventh question by S3 and S4 is given in Figure 11.

Figure 11. Description of Function Parameters by a Group

Finally, the four students were asked about the points they liked and disliked about the activity. The students said that they had fun while doing the activity and that the activity contributed positively to their perceptions of mathematics. For example, a student (S4) commented that "We had fun and we recognized the role and necessity of mathematics in our daily lives." Regarding the points that they did not like, the students said that the story was too long, they had difficulty writing the functions, and the sub-question "Initial prediction and the reason" in the fourth question was unnecessary.

CONCLUSIONS and SUGGESTIONS

In this article, an activity where students experienced all the steps of the mathematical modeling process has been described. The students worked with interest on the activity during the course of two lessons, found a solution to a problem arising from real life by building a mathematical model, and interpreted the solution in the problem context. Classroom observations indicate that the students' knowledge about renewable energy sources, which is the focus of the activity, and their awareness about saving energy increased. Considering the importance of mathematical modeling both in mathematics and in other fields (Bliss et al., 2014; Erbaş et al., 2014), the activity shared in this article might contribute to the studies conducted in the field of mathematical modeling. Researchers can use the current or similar activities in their studies. Additionally, with the increase and sharing of such activities, the mathematical modeling could be taught more frequently in schools or teaching mathematics using modeling can become more widespread.

Based on the experience gained in the current study, some suggestions can be made to the educators who might use the activity in the future. First of all, although the province of the school is a city with a coastal edge, most of the students were not familiar with the boat and sailing culture. Therefore, one suggestion for teachers is to do a short research on this topic, at least to learn the meaning of the terms in the first table on the worksheet. Secondly, some students had difficulty in deciding the points that would be included in the graph during the whole class implementation. Based on this

observation, a row has been added to the table in the second question of the worksheet. Teachers should emphasize the use of cumulative total when creating the graph. Finally, all groups except one group identified the energy source which is compatible with the model they created at their first try. There was only one group that revised the electricity consumption model. In future use of the activity, there could be opportunities to modify the models. For example, teachers may ask students to revise a model that they prepared prior to the lesson.

In this study, the mathematical dimension of the activity was enriched after the whole class teaching by asking students to write function rules for solar panel electricity generation. In future use of the activity, the mathematical dimension of activity can be further deepened. For example, students may be asked to find formulas for all of the graphs they plot and compare them. Or, students can compare the slopes of the linear functions they have determined at different intervals and discuss their meaning. Regarding the mathematical dimension, in the second implementation of the activity, the students actually created a regression line without using this term. Given that real-life data do not always perfectly fit a function, the concept of regression could be included in high school mathematics curriculum. In such a case, technology could be used to determine the regression line.

In the current secondary mathematics curriculum, the importance of mathematical modeling is briefly mentioned in the philosophy and general objectives sections but the modeling process is not elaborated (MoNE, 2018). Previously, mathematical modeling was given schematically in the mathematics curriculum in 2013 and the modeling steps were explained (MoNE, 2013). Mathematical processes such as mathematical modeling should be more emphasized in the mathematics curriculum which is the main source of reference for mathematics teachers.

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Citation Information

Appendix 1

Activity Worksheet

Sun or Wind?

Renewable Energy: It is the energy produced by using natural resources that are inexhaustible. Solar, wind, and water are examples of renewable energy sources.

Problem: Suppose that you bought a new sailboat. You aim to use renewable energy sources in your boat. Your financial situation is only enough to buy a solar panel or a wind turbine generating an average of 2100 watts of electricity per day. Which energy source would you prefer? Explain the rationale of your choice by creating a mathematical model.

1) First of all, you should decide which electrical appliances you will use on the boat, like any other seaman. Fill in the table below to determine your electricity consumption. Note that you should not exceed 2100 watts. The electricity values given are approximates.

Electrical Appliances to be used on the Boat

Electrical Appliance	Electricity Consumed per Hour (watt)	Duration of Use (hour)	Daily Electricity Consumption
Refrigerator	60		
Freezer	70		
Lighting	120		
TV	75		
Stereo	50		
Laptop	50		
Oven	1800		
Dishwasher	1800		
Washing Machine	800		
Iron	2700		
Coffee Machine	900		
Electric Winch	1000		
Electric Windlass	1000		
Navigation	50		
Autopilot	60		
Water Booster	120	0.5 hour	60
Total			

2) An important point in the use of energy is the time at which electricity is used. Determine the time distribution of your electricity consumption by completing the table below.

Distribution of Consumed Electricity

Time Interval	7:00 - 9:00	9:00 - 11:00	11:00-13:00	13:00-15:00	15:00-17:00	17:00-19:00	19:00-21:00	21:00-23:00	23:00-01:00	01:00-03:00	03:00-05:00	05:00-07:00
Electricity Consumed (watt)												
Total												
Cumulative Total												

3) To better understand the distribution of your electricity consumption throughout the day, draw the graph of the "Total Electricity Consumption Versus Time" on the graph paper. Which variables should be on the horizontal axis and on the vertical axis?

When creating the time axis, take 7 am as zero. When creating the graph, use the cumulative total values found in the last row of the table in the second question. Your points must be in the form of (0,0), (2,cumulative total value 1), (4,cumulative total value 2), and so on.

4) You have now determined your electricity consumption. What energy source is more suitable for your need? The table below shows the average amount of electricity that can be produced on a typical summer day for the solar panel and wind turbine. Examine the table to determine which energy source to choose and record your answer below the table.

Electricity Produced by Solar Panel and Wind Turbine

Measurement Time	Electricity Produced by Solar Panel (watt)	Electricity Produced by Wind Turbine (watt)
07:00	0	0
09:00	100	50
11:00	500	200
13:00	1050	450
15:00	1600	750
17:00	1950	800
19:00	2100	900
21:00	2100	900
23:00	2100	1000
01:00	2100	1400
03:00	2100	1700
05:00	2100	1950
07:00	2100	2100

Initial prediction and the reason:

5) To better examine the relationship between electricity generation and consumption, plot the following graphs: Plot the electricity generation of the solar panel in one of the graph paper that includes the electricity consumption graph. Graph the electricity generated by the wind turbine on the other consumption graph.

6) Which energy source would you prefer based on the graphs you created? Write down the reason. You may change your electricity consumption model if needed. If you've made changes, write down the changes you made and the reason.

7) Write one (or more) functions representing the electricity generation of the solar panel. Explain the meaning of the parameters in the function.

Appendix 2

Graph Paper

y

x